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Comparison of Craniofacial Features of Major Human Groups

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ABSTRACT Distance analysis and factor analysis, based on Q-mode correlation coefficients, were applied to 23 craniofacial measurements in 1,802 recent and prehistoric crania from major geographical areas of the Old World. The major findings are as follows: 1) Australians show closer similarities to African populations than to Melanesians. 2) Recent Europeans align with East Asians, and early West Asians resemble Africans. 3) The Asian population complex with regional difference between northern and southern members is manifest. 4) Clinal variations of craniofacial features can be detected in the Afro-European region on the one hand, and Australasian and East Asian region on the other hand. 5) The craniofacial variations of major geographical groups are not necessarily consistent with their geographical distribution pattern. This may be a sign that the evolutionary divergence in craniofacial shape among recent populations of different geographical areas is of a highly limited degree. Taking all of these into account, a single origin for anatomically modern humans is the most parsimonious interpretation of the craniofacial variations presented in this study.

In recent years, mitochondrial and nuclear DNA analyses, as well as cytogenetic studies, have opened new channels in the investigation of anatomically modern humans' diversity and relationships (Nei and Roychoudhury, 1974; Horai et al., 1986; Wainscoat et al., 1986; Cann et al., 1987; Cavalli-Sforza et al., 1988; Vosberg, 1989; Long et al., 1990; Rapacz et al., 1991; Papiha et al., 1991; Vigilant et al., 1991; Wilson and Cann, 1992). The main conclusion reached by these researchers is that there has been rapid world-wide replacement by migration from a single source, subsaharan Africa, ca. 200,000 years B.P. This single-origin, or "Out of Africa," hypothesis has been further supported by a paleoanthropological standpoint (Stringer and Andrews, 1988; Valladas et al., 1988; Stringer, 1990). However, several controversies have arisen concerning the genetic evidence (Weise and Maruyama, 1976; Excoffier et al., 1987; Saitou and Omoto, 1987; Sanchez-Mazas and Langaney, 1988; Spuhler, 1988; Excoffier and Langaney, 1989; Maddison, 1991; Hedges et al., 1992; Nei, 1992; Templeton, 1992, 1993; Klein et al., 1993).

An alternative explanation to the origin of anatomically modern humans has been proposed. The classic regional-continuity model or polycentric view of modern human emergence proposed by Weidenreich (1943, 1945, 1951) and Coon (1962) has been succeeded and outlined in a broader theoretical context by Wolpoff and his colleagues as the multiregional-evolution model (Wolpoff, 1980, 1985, 1989; Thorne and Wolpoff, 1981; Wolpoff et al., 1984, 1988). The multiregional-evolution model argues that there is considerable morphological and genetic con-

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TABLE 1. Materials used in the present study (male samples)

Sample name	N	Reference	Provenience
Australians			
New South Wales	35	Present study	Recent Australian Aborigines from New South Wales (Australian Museum, Sydney)
South Australia	135	Present study	Recent Australian Aborigines from Adelaide, South Australia (South Australian Museum, Adelaide)
Roonka	46	Present study	600–4250 years B.P. Roonka site, Murray River, South Australia (South Australian Museum, Adelaide)
Melanesians			
Papua New Guinea	88	Present study	Recent Papuans, Purari River delta, Fly River delta, Sepik River delta, and other region (Australian Museum, Univ. Sydney)
Santa Cruz	10	Present study	Recent Santa Cruz islanders (Australian Museum, Univ. Sydney, South Australian Museum)
Solomon	41	Present study	Recent Solomon islanders (Australian Museum, Univ. Sydney, South Australian Museum)
New Britain	23	Present study	Recent New Britain islanders (Australian Museum, Univ. Sydney, South Australian Museum)
Vanuatu	18	Present study	Recent New Hebrides islanders No artificially deformed crania are selected (Australian Museum, Univ. Sydney, South Australian Museum)
New Caledonia	18	Present study	Recent New Caledonia islanders (Australian Museum, Univ. Sydney, South Australian Museum)
New Ireland	26	Present study	Recent New Ireland islanders (Australian Museum, Univ. Sydney, South Australian Museum)
Fiji	26	Present study	Recent Fiji islanders (Australian Museum, South Australian Museum, Bishop Museum, Univ. of Tokyo)
Southeast Asians			
Malay-Indonesian	11	Present study	Eight Malayans and 3 Indonesians (South Australian Museum, Univ. Sydney, Univ. of Tokyo)
Bornean	18	Present study	Recent Dayak tribe, Pontianak, Kapuas River (Univ. of Tokyo, Kyoto Univ, Univ. Sydney, South Australian Museum)
Early Thai	17	Present study	Early metal age of Thailand (ca. 3,000–6,000 years B.P.) Ban Chiang site, Nong Han dist., of Udon Thani province in northeast Thailand (Univ. of Hawaii-Manoa)
East Asians			
Jomonese	113	Hanihara (1993a,b)	Middle, Late, and the Latest Jomon periods (ca. 5,300–2,300 years B.P.), excavated from many sites in Japan (Univ. of Tokyo, National Science Museum)
Japanese	140	Hanihara (1993b)	Recent Japanese from Honshu, Japan (Univ. of Tokyo, Kyoto Univ.)
Chinese	71	Hanihara (1993a,b)	Northern part of China (19th cent.) (Univ. of Tokyo)
Korean	36	Hanihara (1993a,b)	Recent Koreans (Univ. of Tokyo, Kyoto Univ.)
Taiwanese	19	Hanihara (1993a,b)	Recent Taiwanese, including Atayal tribe (Univ. of Tokyo)
Polynesians			
New Zealand	30	Present study	Recent Maori and Moriori tribes (Australian Museum, Univ. Sydney, South Australian Museum, Univ. of Tokyo)
Tonga-Samoa	9	Present study	Recent Tongans and Samoans (Australian Museum, Bishop Museum)
Oahu	56	Hanihara (1993a,b)	Mokapu site of Oahu Island, pre-contact population (A.D. 1385–A.D. 1778) (Bishop Museum)
Hawaii	99	Hanihara (1993a,b)	Hawaii, Molokai, Lanai, Maui, and Kauai islanders, probably pre-contact (Bishop Museum)
Micronesians			
Guam	115	Hanihara (1993a,b)	Chamorros from Guam island, pre-contact population (Bishop Museum)

(*continued*)

TABLE 1. *Materials used in the present study (male samples) (continued)*

Sample name	N	Reference	Provenience
West Asians			
Early Iranian	32	Present study	From Bronze-Iron age to Islamic period through Achaemenian, Dailaman district of north Iran (Univ. of Tokyo)
European			
German	22	Present study	Recent Germans (Univ. of Tokyo)
Russian	17	Present study	Recent Russians (Univ. of Tokyo)
Czechoslovakian	28	Present study	Recent Czechoslovakians Central Moravia (South Aust. Mus.) (Univ. of Tokyo, South Australian Museum)
African			
Natal Nguni	165	Villiers (1968)	South African Bantu-speaking Negros Zulu and Swazi tribes
Cape Nguni	127	Villiers (1968)	South African Bantu-speaking Negros Xosa, Pondo, Fingo, Hlubi, and Baca tribes
Southern Sotho	154	Villiers (1968)	South African Bantu-speaking Negros Including 24 individuals from western and eastern Sotho, Sotho, Tswana, Rolong, and Pedi tribes
Shangana-Tonga	57	Villiers (1968)	South African Bantu-speaking Negros Shangaan, Tonga, Inhambane, and Mozambique tribes

tinuity across the archaic-modern human boundary in several geographical regions, such as Africa, Europe (including West Asia), East Asia, and Australasia. Some human genetic data provide considerable insights into the multiregional model (Spuhler, 1988; Li and Sadler, 1991; Xiong et al., 1991).

As compared with the two simplified alternatives, a less extreme "Out of Africa" model, which assumes a complex hybridization and replacement process, has been proposed (Rightmire, 1979, 1986; Bräuer, 1984, 1989, 1992; Smith, 1985; Smith et al, 1989; Bowcock et al., 1991; Pope, 1992a). The less extreme replacement alternatives allow for only a limited degree of continuity, because the fossil record shows that the conception of numerous indigenous evolutionary lines leading to anatomically modern humans is not well supported by the available evidence (Bräuer, 1984, 1989, 1992; Stringer and Andrews, 1988; Habgood, 1989, 1992; Smith et al., 1989).

Other interpretations for the origin of anatomically modern humans have been proposed for late Pleistocene human evolution in West Asia (Trinkaus, 1983, 1984; Vandermeersch, 1989, 1992) and in Southeast Asia (Turner, 1992a,b), and several scientific volumes and reviews have been recently published bearing on the origin of modern humans (Smith and Spencer, 1984; Mellars and Stringer, 1989; Smith et al., 1989; Trinkaus, 1989; Bräuer and Smith, 1992; Akazawa et al., 1992; Pope, 1992b; Aitken et al., 1993; Long, 1993; Brenner and Hanihara, 1995).

In the field of morphological studies, investigations have mainly been based on comparisons between anatomically modern humans and archaic humans (e.g., Neanderthals, *Homo erectus*) through various cladistic and, to a lesser extent, phenetic approaches to reconstructing evolutionary history (Wolpoff et al., 1984; Wolpoff, 1992; Stringer and Andrews, 1988; Trinkaus, 1986, 1992; Lieberman, 1995). The proponents of the multiregional hypothesis emphasize the existence of gradualistic evolutionary trends or "clade" characters in each region (Thorne and Wolpoff, 1981; Wolpoff, 1985, 1989, 1992; Habgood; 1989, 1992). Proponents of the "Out of Africa" hypothesis challenge many of the supposed "regional" characters that are used to link some modern populations with their supposed archaic predecessors (Stringer, 1992). Coinciding with these broader debates, there has been much discussion of the species concept in palaeoanthropology in recent years (Rightmire, 1986; Tattersell, 1986; Leventon, 1988; Smith et al., 1989; Stringer, 1992). Further, there are persistent dating problems concerning the period of transition from the last archaic to the earliest modern *Homo sapiens* (Smith et al., 1989).

Delson (1988) has supported the single-

TABLE 2. Basic statistics for each sample

Sample name	Max. cranial l. (M1) N	Mean	S.D.	C.V.	Cranial base l. (M5) N	Mean	S.D.	C.V.
New South Wales	28	187.5	5.87	0.0313	26	101.1	4.22	0.0417
South Australia	115	188.5	6.33	0.0336	91	101.6	4.57	0.0450
Roonka	39	189.6	7.18	0.0379	7	101.6	4.89	0.0482
Papua New Guinea	79	182.7	6.02	0.0330	82	98.9	2.98	0.0302
Santa Cruz	10	186.3	5.40	0.0290	10	99.4	4.17	0.0419
Solomon	40	181.7	5.55	0.0306	36	99.6	4.02	0.0404
New Britain	21	185.4	6.71	0.0362	21	102.1	4.35	0.0426
Vanuatu	17	185.3	5.44	0.0294	17	99.3	2.59	0.0261
New Caledonia	15	183.1	6.84	0.0374	16	100.8	2.88	0.0286
New Ireland	25	182.5	6.55	0.0359	25	99.8	3.30	0.0331
Fiji	25	191.0	6.49	0.0340	20	103.5	4.65	0.0450
Malay-Indonesian	11	176.0	9.07	0.0516	10	98.7	3.78	0.0383
Bornean	17	178.6	5.42	0.0304	17	99.4	4.23	0.0425
New Zealand	29	185.8	7.41	0.0399	26	102.1	3.94	0.0386
Tonga	8	178.9	7.02	0.0392	6	106.8	5.49	0.0514
Early Iranian	28	187.5	7.19	0.0383	12	104.1	4.26	0.0409
German	19	180.4	7.80	0.0432	22	98.6	4.26	0.0432
Russian	17	181.7	6.36	0.0350	16	102.8	4.06	0.0395
Czecho	28	176.0	5.14	0.0292	28	99.1	4.37	0.0441

Max. cranial b. (M8) N	Mean	S.D.	C.V.	Min. frontal b. (M9) N	Mean	S.D.	C.V.	Basion-bregma h. (M17) N	Mean	S.D.	C.V.
29	131.8	4.54	0.0345	28	97.0	4.41	0.0454	27	134.0	4.53	0.0338
115	123.0	5.01	0.0385	119	95.6	5.45	0.0575	90	129.7	5.00	0.0385
39	129.4	6.31	0.0488	38	95.6	5.30	0.0555	10	129.6	5.15	0.0397
79	129.1	5.03	0.0390	83	94.0	4.78	0.0508	83	131.7	5.15	0.0391
10	127.9	4.63	0.0362	10	93.0	3.43	0.0369	10	132.4	4.06	0.0307
38	130.3	5.20	0.0399	40	92.2	5.35	0.0581	35	135.0	4.72	0.0350
21	133.6	4.67	0.0350	21	93.8	5.72	0.0610	21	138.1	4.23	0.0306
16	130.3	4.91	0.0377	17	91.5	5.89	0.0643	17	130.8	5.55	0.0425
16	133.1	4.18	0.0314	16	95.0	4.90	0.0516	16	136.4	5.61	0.0411
25	135.4	7.27	0.0537	25	94.0	5.13	0.0546	24	134.7	4.51	0.0334
24	134.6	6.00	0.0446	25	96.2	4.71	0.0489	20	138.6	4.24	0.0306
11	139.8	3.62	0.0259	11	94.9	6.26	0.0660	11	132.7	4.54	0.0342
18	135.7	5.63	0.0415	18	92.7	4.92	0.0531	17	135.3	4.57	0.0337
29	139.5	6.34	0.0455	29	95.0	3.84	0.0404	26	134.7	4.45	0.0330
8	148.8	5.70	0.0383	8	98.4	3.74	0.0380	7	142.6	4.54	0.0318
28	134.2	5.73	0.0427	28	93.6	4.28	0.0457	14	136.8	4.68	0.0342
16	146.3	3.61	0.0247	20	98.9	5.78	0.0584	17	130.8	5.32	0.0407
17	144.7	3.53	0.0244	17	97.5	4.14	0.0425	16	134.8	5.58	0.0414
28	149.0	4.51	0.0303	28	98.9	3.51	0.0355	28	134.3	5.97	0.0444

Sagit. front. arc (M26) N	Mean	S.D.	C.V.	Sagit. par. arc (M27) N	Mean	S.D.	C.V.	Sagit. occip. arc (M28) N	Mean	S.D.	C.V.
29	131.4	4.89	0.0372	29	128.5	6.84	0.0532	26	118.0	5.98	0.0507
121	128.3	6.34	0.0494	123	124.4	6.52	0.0524	104	114.7	5.96	0.0520
31	128.8	6.50	0.0505	39	130.3	5.76	0.0442	18	113.2	4.44	0.0392
83	124.2	5.35	0.0431	82	129.4	6.45	0.0498	79	115.1	6.99	0.0607
10	126.6	8.54	0.0675	10	135.0	5.98	0.0443	10	114.6	3.31	0.0289
41	125.1	5.12	0.0409	39	130.0	7.59	0.0584	36	116.6	7.80	0.0669
21	125.6	6.14	0.0488	21	132.7	5.81	0.0438	21	116.5	6.52	0.0560
17	124.2	4.49	0.0360	17	133.8	8.81	0.0659	17	111.5	4.02	0.0360
16	128.2	4.23	0.0330	16	131.3	7.36	0.0561	15	114.9	7.29	0.0635
25	124.2	7.30	0.0587	25	130.2	7.33	0.0563	23	114.0	6.60	0.0578
25	130.0	6.98	0.0537	25	133.8	6.94	0.0519	24	124.1	6.98	0.0563
11	126.4	5.16	0.0408	12	124.1	9.98	0.0804	11	108.4	9.44	0.0870
18	127.8	4.05	0.0317	18	132.4	8.39	0.0633	17	109.7	4.79	0.0437
28	130.5	4.50	0.0345	29	124.4	9.49	0.0763	26	118.0	8.81	0.0746
8	128.5	5.73	0.0446	9	124.6	8.63	0.0693	9	115.0	9.26	0.0805
28	130.1	6.58	0.0506	30	128.0	8.09	0.0632	23	115.8	8.26	0.0713
18	130.6	7.06	0.0540	18	123.9	9.14	0.0738	17	114.0	8.73	0.0765
17	129.0	4.09	0.0317	15	126.1	8.77	0.0695	16	115.4	6.31	0.0547
28	127.9	7.06	0.0552	28	122.4	5.94	0.0485	28	111.6	6.15	0.0551

(continued)

TABLE 2. Basic statistics for each sample (continued)

Sagit. front. chord (M29)				Sagit. par. chord (M30)				Sagit. occip. chord (M31)			
N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.
30	113.3	4.76	0.0421	30	116.3	5.69	0.0489	27	96.7	4.98	0.0515
122	111.8	4.70	0.0421	123	113.3	5.14	0.0453	104	93.2	3.98	0.0427
31	111.4	5.06	0.0455	39	118.1	5.78	0.0489	17	94.1	3.76	0.0399
83	109.3	3.84	0.0351	79	116.1	5.18	0.0447	76	96.1	4.68	0.0487
10	110.9	6.44	0.0580	10	120.5	5.23	0.0434	10	94.3	2.63	0.0279
41	110.0	4.31	0.0392	40	115.6	5.35	0.0463	36	96.1	5.46	0.0569
21	111.3	5.25	0.0471	21	118.4	4.60	0.0388	21	98.3	4.73	0.0481
17	111.2	3.43	0.0309	17	118.8	6.15	0.0517	17	93.2	3.67	0.0393
16	113.0	3.35	0.0296	16	115.6	7.04	0.0609	15	96.6	5.36	0.0554
25	109.9	5.30	0.0483	25	116.3	6.06	0.0521	23	95.6	4.11	0.0430
25	115.1	5.35	0.0465	25	119.2	5.28	0.0443	24	100.4	4.69	0.0467
11	111.3	3.59	0.0323	12	108.9	9.36	0.0859	11	92.6	9.68	0.1045
18	111.4	3.31	0.0297	18	116.5	7.73	0.0664	17	93.4	3.32	0.0355
28	115.3	4.04	0.0351	29	112.1	7.71	0.0688	26	98.4	6.97	0.0709
8	114.0	5.13	0.0450	9	109.1	7.24	0.0663	9	97.7	5.29	0.0542
28	115.2	4.69	0.0407	30	114.3	6.43	0.0563	23	96.4	7.40	0.0768
18	113.5	5.80	0.0511	17	112.3	7.64	0.0680	17	93.4	4.99	0.0534
17	113.4	3.73	0.0329	16	112.4	7.62	0.0677	16	95.8	5.25	0.0548
28	111.3	5.15	0.0463	28	109.8	4.87	0.0444	28	92.7	5.11	0.0551

Facial length (M40)				Bizygomatic b. (M45)				Middle facial b. (M46)			
N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.
26	103.6	4.39	0.0424	21	133.2	6.42	0.0482	24	94.5	5.90	0.0624
76	106.3	5.23	0.0492	70	131.0	5.96	0.0455	85	95.3	5.06	0.0531
9	105.7	4.72	0.0446	18	134.9	6.34	0.0470	20	94.9	5.54	0.0584
76	102.3	4.21	0.0411	75	128.3	5.09	0.0397	80	95.6	3.81	0.0398
7	105.7	4.11	0.0389	9	129.7	4.56	0.0351	10	96.1	3.14	0.0327
28	100.7	3.89	0.0386	34	131.0	5.07	0.0387	37	95.6	5.07	0.0531
19	105.8	5.13	0.0485	20	134.8	4.73	0.0351	20	97.1	4.05	0.0417
15	105.3	4.65	0.0442	14	133.3	3.95	0.0296	15	95.8	4.13	0.0431
14	106.1	4.74	0.0446	14	134.6	5.65	0.0420	15	98.0	6.95	0.0709
23	102.4	4.79	0.0468	21	132.2	6.18	0.0467	23	95.7	4.30	0.0449
15	103.6	3.70	0.0357	22	132.1	6.92	0.0524	22	98.1	5.53	0.0564
9	102.4	4.93	0.0481	10	132.5	5.05	0.0381	9	99.6	4.62	0.0463
16	96.6	4.92	0.0510	17	133.0	6.56	0.0493	16	99.8	3.76	0.0377
24	99.2	5.72	0.0576	24	136.1	6.91	0.0508	22	99.3	4.48	0.0452
5	102.4	7.09	0.0693	4	142.5	8.10	0.0569	5	101.2	3.70	0.0366
12	100.4	7.81	0.0778	14	129.6	4.76	0.0367	14	98.4	4.94	0.0502
22	94.6	5.29	0.0559	20	134.5	4.82	0.0358	20	94.8	4.14	0.0437
16	98.6	4.90	0.0497	17	136.2	4.52	0.0332	16	97.2	4.55	0.0468
27	94.3	4.62	0.0489	27	135.0	4.54	0.0337	28	95.6	5.51	0.0576

Upper facial h. (M48)				Orbital b. (M51a)				Orbital h. (M52)			
N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.
27	66.2	3.46	0.0523	26	42.1	1.72	0.0408	27	34.1	1.73	0.0508
90	65.7	3.66	0.0556	91	41.4	1.64	0.0396	98	33.6	1.81	0.0540
20	64.6	4.84	0.0750	15	41.2	1.86	0.0451	33	33.6	2.11	0.0628
80	66.8	3.58	0.0535	82	39.6	1.36	0.0343	83	34.1	1.91	0.0562
8	64.8	4.65	0.0718	10	41.4	1.17	0.0284	10	33.4	2.07	0.0618
33	64.4	4.37	0.0678	41	40.1	1.18	0.0294	41	33.5	1.58	0.0473
19	66.4	4.82	0.0726	21	40.4	1.50	0.0371	21	32.8	1.81	0.0550
16	65.3	3.34	0.0512	16	40.8	1.48	0.0364	16	32.6	2.13	0.0654
14	65.7	3.47	0.0529	16	40.9	2.47	0.0605	16	33.0	2.07	0.0626
23	67.1	5.39	0.0804	24	40.8	1.15	0.0283	24	34.0	1.78	0.0523
20	67.4	5.86	0.0870	23	41.2	1.97	0.0478	23	34.6	2.91	0.0840
10	66.2	4.36	0.0658	11	39.7	1.38	0.0348	11	33.9	2.54	0.0752
18	64.8	4.03	0.0622	18	39.4	1.46	0.0371	18	33.7	1.99	0.0591
25	67.6	4.84	0.0715	25	40.9	1.88	0.0459	26	35.0	2.01	0.0574
6	65.2	2.79	0.0428	7	41.4	1.51	0.0365	7	34.9	1.57	0.0451
17	70.8	3.39	0.0478	15	38.8	2.49	0.0641	19	33.5	1.69	0.0505
21	68.9	4.49	0.0652	22	39.6	1.63	0.0411	22	33.9	1.74	0.0514
17	69.9	2.98	0.0426	17	40.1	2.01	0.0503	17	33.2	2.36	0.0710
26	68.4	4.16	0.0608	28	39.9	1.70	0.0425	28	32.4	2.12	0.0652

(*continued*)

TABLE 2. Basic statistics for each sample (continued)

Nasal h. (M54)				Nasal b. (M55)				Maxilloalveol. b. (M61)			
N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.
29	27.7	1.81	0.0653	27	50.1	2.24	0.0447	30	68.2	3.36	0.0493
91	27.4	2.01	0.0734	92	49.8	2.46	0.0493	92	67.1	3.17	0.0473
27	28.3	1.68	0.0594	19	50.3	3.43	0.0682	28	67.7	4.74	0.0701
83	25.7	1.68	0.0654	79	50.8	2.48	0.0488	81	64.7	3.33	0.0515
10	27.2	1.81	0.0667	10	48.7	3.65	0.0750	6	64.5	3.02	0.0468
40	25.6	2.23	0.0869	41	49.9	3.04	0.0610	32	63.4	4.20	0.0662
21	27.2	1.91	0.0704	21	50.1	2.96	0.0591	20	66.0	3.78	0.0573
16	26.8	1.97	0.0736	16	48.9	1.67	0.0341	15	65.7	3.02	0.0459
15	26.4	2.38	0.0903	16	48.8	2.38	0.0488	15	66.1	3.80	0.0574
25	26.0	1.49	0.0572	24	51.0	3.13	0.0615	23	65.2	3.59	0.0551
23	26.1	1.94	0.0742	23	51.5	4.90	0.0951	23	64.1	3.44	0.0537
10	27.3	1.86	0.0681	10	52.3	2.25	0.0430	10	68.5	4.28	0.0625
17	27.1	1.92	0.0709	17	50.4	3.06	0.0608	13	63.4	2.47	0.0389
24	26.2	1.28	0.0490	26	53.2	3.42	0.0643	25	63.7	3.62	0.0569
7	26.0	2.31	0.0888	7	53.1	4.49	0.0845	6	62.2	2.56	0.0412
19	25.0	2.34	0.0936	18	53.7	2.64	0.0491	17	63.1	4.17	0.0661
21	24.6	1.96	0.0797	22	52.0	2.95	0.0568	21	61.6	4.50	0.0731
17	24.7	1.90	0.0768	17	52.5	2.21	0.0421	17	64.5	3.32	0.0515
28	24.2	1.87	0.0773	28	50.7	2.72	0.0536	26	61.2	4.55	0.0744

Bicondylar b. (M65)				Bigonial b. (M66)				Mandibular l. (M68 (1))			
N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.	N	Mean	S.D.	C.V.
18	118.3	6.60	0.0558	23	101.1	10.34	0.1024	21	109.4	5.07	0.0464
43	115.7	6.30	0.0545	52	99.4	7.78	0.0783	44	111.1	4.75	0.0428
21	117.2	8.68	0.0740	36	96.9	10.54	0.1088	24	111.0	5.99	0.0539
43	115.9	5.18	0.0447	50	95.1	3.81	0.0400	34	108.4	6.77	0.0625
6	118.5	4.89	0.0413	7	89.0	4.73	0.0531	5	109.4	2.19	0.0200
14	120.9	5.13	0.0424	17	98.2	6.44	0.0655	14	103.2	4.98	0.0482
18	119.8	4.77	0.0398	20	98.9	7.41	0.0750	18	107.2	7.12	0.0665
6	118.0	4.05	0.0343	7	94.3	4.54	0.0481	6	107.2	6.01	0.0561
4	118.5	3.11	0.0262	4	90.3	9.29	0.1029	4	106.5	1.73	0.0163
13	114.5	6.94	0.0606	14	95.2	6.12	0.0642	14	104.3	6.21	0.0595
12	118.3	5.19	0.0439	14	97.6	7.28	0.0746	11	109.2	3.46	0.0317
8	115.6	3.05	0.0264	8	98.6	3.29	0.0333	8	102.8	4.82	0.0469
10	120.2	8.31	0.0691	11	99.8	8.49	0.0851	10	104.7	5.36	0.0511
8	118.1	4.67	0.0396	11	98.7	4.84	0.0490	8	105.3	5.12	0.0486
4	129.0	4.97	0.0385	6	103.3	7.34	0.0710	4	109.8	3.77	0.0344
8	114.8	8.48	0.0739	12	100.4	6.13	0.0610	8	107.3	4.71	0.0439
18	122.6	5.47	0.0446	18	101.2	8.02	0.0792	18	110.3	5.44	0.0494
11	120.7	4.76	0.0394	11	105.5	7.55	0.0716	11	107.5	2.94	0.0274
13	120.7	4.73	0.0392	13	104.3	2.08	0.0200	13	105.3	5.86	0.0556

origin hypothesis for modern humans, but has remarked that "it also clouds the apparent continuity of all varieties of *Homo* in the later Pleistocene and may lead to recognition of greater taxonomic distinction among living humans than is warranted." He emphasized the necessity of the study of morphological diversity within modern populations by comparing intragroup variation of archaic humans, including Neanderthals, to determine whether these populations should be placed in separate species or retained within a temporally and geographically polytypic species of *Homo sapiens* (Delson, 1988). With this perspective in mind, Howells (1989) has published a pioneering study. Howells, applying multivariate analyses to a large battery of craniofacial measurements, concludes that all recent human populations from around the world are more closely related to each other than they are to archaic Neanderthals. Howells' study, using morphological variation, further addresses the question of origins and affinities of anatomically modern humans. More recently, several other authors have made similar attempts to elucidate modern human origins using craniofacial and dental variation of worldwide populations (Turner 1992a,b, 1995; Lahr, 1994; Lahr and Foley, 1994; Relethford, 1994; Relethford and Harpending, 1994).

In these studies, close multivariate craniofacial and dental correspondences between

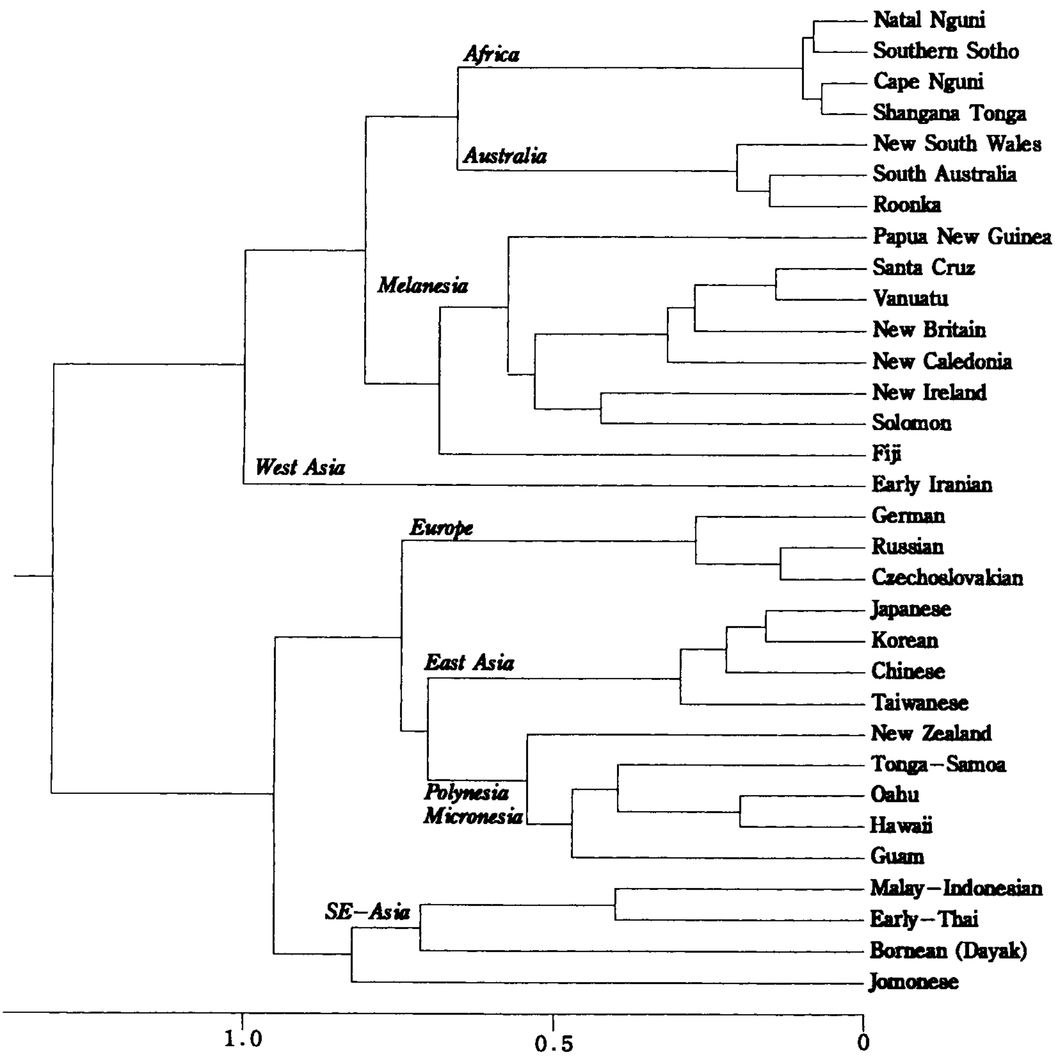

Fig. 1. Cluster analysis applied to Q-mode correlation matrix between every pair of samples.

recent Africans and Australians were found (Howells, 1989; Brace et al., 1990; Turner, 1992a; Lahr, 1994). The close relationship between Africans and Australo-melanesians is certainly not a new idea (Birdsell, 1972; Kirk, 1976). At the same time, human genetic studies and comparative morphological studies of craniofacial features have pointed out the relatively close similarity between East Asians and Europeans (Cavalli-Sforza et al., 1988; Howells, 1989).

These findings contrast with Weidenreich's (1943) and Coon's (1962) version of the regional continuity model in which the local lineages evolved independently, and to a lesser extent, with recent versions of this model which emphasize the role of gene flow in maintaining grade similarity while preventing speciation along with the development and persistence of regional features, particularly in peripheral areas (the "center and edge" corollary) (Wolpoff, 1985, 1989, 1992). On the other hand, the single-origin hypothesis predicts different patterns of variation in comparing African populations with those from other regions. The popula-

TABLE 3. Contribution rate and co-ordinate score of multidimensional scaling

	Dimension				
	1	2	3	4	5
Eigenvalue	12.535	4.961	3.197	2.150	1.854
Contribution rate	53.670	21.242	13.686	9.206	2.937
Cumulative contr.	53.670	74.911	88.598	97.804	100.000
Scores for each sample					
New South Wales	−0.6432	−0.1146	−0.1738	0.0341	−0.2868
South Australia	−0.6095	−0.2400	−0.2625	0.2892	−0.3029
Roonka	−0.8556	−0.0108	−0.3044	0.2347	−0.1111
Papua New Guinea	−0.6014	0.2477	0.5254	0.4338	−0.0348
Santa-Cruz	−0.9194	0.1923	0.1015	−0.0111	−0.0650
Solomon	−0.2312	0.6944	0.3059	−0.3598	−0.0261
New Britain	−0.6774	0.4909	0.0256	−0.1913	0.0571
Vanuatu	−0.8019	0.4306	−0.1143	0.1596	0.0123
New Caledonia	−0.6925	0.1804	−0.2740	−0.4684	−0.0172
New Ireland	−0.4433	0.5801	0.1812	0.1095	−0.0974
Fiji	−0.4327	−0.1628	0.7064	−0.3969	−0.3192
Malay-Indonesian	0.2372	0.2647	−0.5918	0.3158	0.3209
Bornean	0.0270	0.5008	−0.2059	0.0545	0.3988
Early Thai	0.4000	0.1820	−0.3567	0.0720	0.6186
Jomonese	0.3129	0.5244	−0.4704	−0.2391	−0.2987
Japanese	0.7354	0.1541	0.4014	−0.0759	−0.1471
Chinese	0.6863	0.1718	0.5595	0.3064	0.0461
Korean	0.8079	0.3108	0.3095	0.2670	−0.0946
Taiwanese	0.7691	0.2461	0.2435	−0.0121	0.3352
New Zealand	0.5369	−0.3810	0.1553	−0.1701	−0.0769
Tonga	0.6370	−0.0605	−0.3656	−0.2162	−0.4204
Oahu	0.8826	−0.6096	−0.0439	−0.4904	0.1747
Hawaii	0.9318	−0.3299	−0.0270	−0.3077	0.0364
Guam	0.8656	0.3158	−0.1301	−0.2455	−0.0167
Early Iranian	0.0303	−0.4575	0.5296	0.2056	0.3819
German	0.5162	−0.5239	−0.0876	0.4498	−0.3095
Russian	0.7090	−0.1767	−0.1419	0.2831	−0.2414
Czechoslovakian	0.6928	−0.0980	−0.3627	−0.1812	−0.2122
Natal Nguni	−0.4440	−0.7162	−0.1007	−0.0038	0.2075
Cape Nguni	−0.6990	−0.4694	−0.0743	−0.1025	0.0968
Southern Sotho	−0.6170	−0.6592	0.0179	0.1215	0.1237
Shangana Tonga	−0.6561	−0.4767	0.0249	−0.2273	0.1997

tion affinities inferred from the comparative studies of predominantly recent human populations, such as those by Howells (1989), Brace et al. (1990), and Turner (1992a), are also inconsistent with those predicted by the "Out of Africa" model. However, such discrepancies do not necessarily indicate that such comparisons among recent populations are useless for addressing issues such as the origins of modern human populations as suggested by Howells (1989). In the present study, which is based on the pioneering studies of Howells (1989), Turner (1992a,b), and Lahr (1994), I attempt to re-investigate modern craniofacial variation in order to elucidate the pattern and magnitude of differences among the major human populations.

MATERIALS AND METHODS

Altogether, 32 adult male samples totaling 1,802 individuals are included in the present study. The names of the populations used in this study, sample sizes, and proveniences are given in Table 1.

The 23 linear dimensions (measured following Bräuer, 1988) and the basic statistical information for each sample are presented in Table 2. Because some of the samples, e.g., Roonka, contain deformed/distorted specimens, the numbers of measurements are reduced in Table 2. The Papua New Guinea sample contains many different specimens from many different parts of this island. Pietrusewsky (1992) analyzed a good number of regional groups from Papua New Guinea, including Purari River Delta, Fly River Delta, Sepik River Delta, etc., and showed that these groups were closely related to each other. On the basis of such findings, several regional groups from Papua New Guinea are combined in the present study. The degree of admixture between "ab-

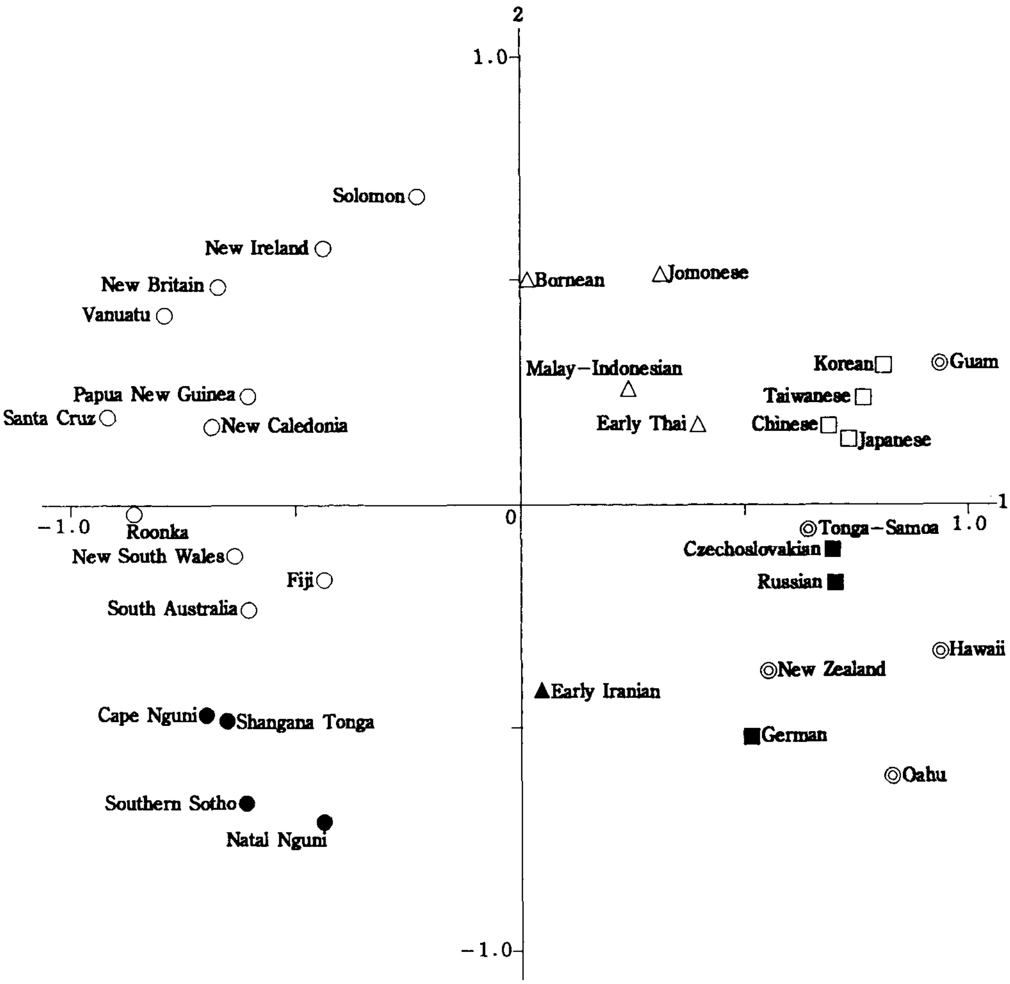

Fig. 2. Two-dimensional graph obtained from multidimensional scaling based on the same matrix (Fig. 1), expressing 74.9% of the total variance. Open circles = Melanesia; double circles = Polynesia and Micronesia; filled circles = Africa; open triangles = Southeast Asia; filled triangles = West Asia; open squares = East Asia; filled squares = Europe.

original" and later-arriving peoples in the Taiwanese sample (Atayal tribe) is unclear, but the S.D. and C.V. of this sample, described elsewhere (Hanihara, 1993a,b), are small enough to warrant including this sample in the present study. According to Ikeda (1968), the craniofacial form of the early Iranian sample used in the present study is somewhat different from that of present Iranian people.

In the present study, all analyses are based on the Q-mode correlation coefficients between pairs of samples. In this method, all raw measurements are rendered into standard form,

$$X' = (X_{ij} - X_i)/\sigma_i$$

where i = number of measurement, j = number of sample, X_{ij} = value of measurement i for sample j, X_i = mean of sample means, and σ_i = S.D. for measurement i.

After this transformation, the correlation coefficients between samples rather than characters are calculated. This method allows the association of pairs of samples to

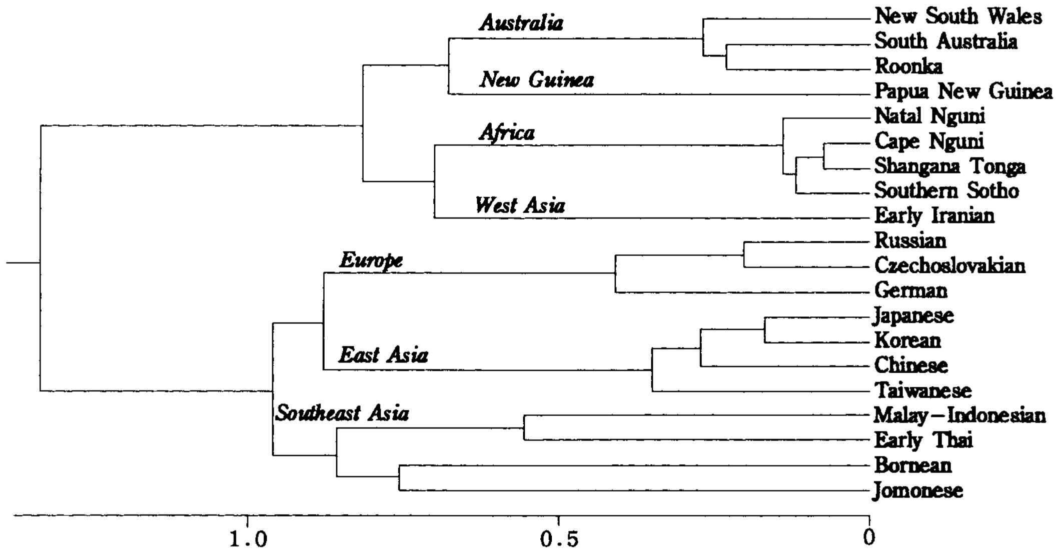

Fig. 3. Dendrogram applied to the Q-mode correlation matrix shown in Table 4.

be examined over all characters (measurement items). Q-mode correlation coefficients represent, accordingly, similarities between pairs of samples. Furthermore, because the correlation coefficients are calculated from the standardized data, size-related variation is effectively removed (Boyce, 1969; Corruccini, 1973, 1987; Sneath and Sokal, 1973; Hanihara, 1979; Howells, 1989). Although Q-mode analysis was developed originally for the purpose of calculating similarity coefficients between individuals, the method can be used to calculate similarities between populations (Stephenson, 1936; Boyce, 1969; Corruccini, 1973, 1987).

Using the Q-mode correlation matrix, cluster analysis, metric multidimensional scaling, and factor analysis were applied in the present study. As described previously, Q-mode correlation matrix is the reverse of the usual procedure, so that the factor pattern gives the loading for samples, not measurements in factor analysis. Howells (1989) observes that Q-mode analysis avoids or alleviates the problems of the usual approach, R-mode analysis, by indicating what measurements or sets of measurements to enter. Such analyses permit a more direct appraisal of population affinities.

In the process of metric multidimensional scaling, using the additive constant for converting comparative distances into absolute distances, it is possible to represent multivariate samples of size N accurately as points $P_1, P_2, \ldots\ldots, P_n$ in a Euclidean space (Torgerson, 1952). The distance coefficients transformed satisfy the following conditions:

1. $d_{ij} \geq 0$ (d_{ij}: distance between samples i and j);
2. $d_{ij} = {}_{ji}$;
3. $d_{ij} = 0$, if $i = j$; and
4. $d_{ij} \leq d_{ik} + {}_{ki}$), where k is referred to the third sample.

The transformed Q-mode correlation coefficients were generated using the following formula:

$$d_{ij} = 1 - s_{ij}/s_{max},$$

where d_{ij} is the transformed distance, s_{ij} is the similarity coefficient between samples i and j, and s_{max} is the maximum value among the similarity coefficients computed.

TABLE 4. Q-mode correlation coefficients between pairs of samples

	1 NSW	2 SA	3 Roonka	4 PNG	5 Malay	6 Borneo	7 E-Thai	8 Jomon	9 Japan	10 China	11 Korea	12 Taiwan	13 E-Iran	14 German	15 Russia	16 Czecho	17 N-N	18 Cape-N	19 S-Sotho	20 S-T
1	1.000																			
2	0.736	1.000																		
3	0.718	0.772	1.000																	
4	0.213	0.272	0.483	1.000																
5	−0.161	0.024	−0.101	−0.152	1.000															
6	−0.138	−0.360	0.140	0.185	0.125	1.000														
7	−0.303	−0.291	−0.364	−0.482	0.435	0.221	1.000													
8	−0.225	−0.273	−0.114	−0.109	0.072	0.242	0.152	1.000												
9	−0.420	−0.433	−0.651	−0.051	−0.031	−0.305	0.135	0.238	1.000											
10	−0.482	−0.490	−0.581	0.106	0.047	−0.065	0.017	−0.136	0.696	1.000										
11	−0.487	−0.420	−0.628	−0.052	0.044	−0.132	0.213	0.232	0.827	0.769	1.000									
12	−0.496	−0.727	−0.696	−0.220	0.102	0.184	0.398	0.203	0.592	0.640	0.707	1.000								
13	−0.172	−0.081	−0.128	−0.074	−0.356	−0.075	0.114	−0.615	−0.083	0.119	−0.122	−0.090	1.000							
14	−0.242	−0.164	−0.309	−0.417	−0.146	−0.240	−0.275	−0.083	−0.033	0.127	0.122	0.124	−0.124	1.000						
15	−0.406	−0.251	−0.452	−0.604	−0.009	−0.258	0.088	0.257	0.215	0.099	0.246	0.023	0.117	0.527	1.000					
16	−0.406	−0.312	−0.495	−0.581	0.173	−0.118	0.084	0.428	0.133	0.001	0.260	0.145	−0.311	0.660	0.796	1.000				
17	0.285	0.224	0.203	−0.086	−0.251	−0.246	−0.155	−0.480	−0.391	−0.461	−0.654	−0.475	0.365	−0.126	−0.341	−0.384	1.000			
18	0.360	0.222	0.431	0.202	−0.400	−0.016	−0.347	−0.228	−0.541	−0.623	−0.757	−0.490	0.214	−0.218	−0.448	−0.452	0.826	1.000		
19	0.385	0.328	0.410	0.157	−0.326	−0.192	−0.350	−0.530	−0.555	−0.523	−0.761	−0.516	0.321	−0.051	−0.436	−0.452	0.881	0.907	1.000	
20	0.376	0.153	0.341	0.140	−0.351	−0.039	−0.241	−0.309	−0.445	−0.487	−0.731	−0.463	0.311	−0.339	−0.439	−0.516	0.879	0.922	0.856	1.000

TABLE 5. Absolute distance of multidimensional scaling, calculated from original distance matrix based on Q-mode correlation coefficients between every pair of samples (additive constant = 0.0653)

	1 NSW	2 SA	3 Roonka	4 PNG	5 Malay	6 Borneo	7 E-Thai	8 Jomon	9 Japan	10 China	11 Korea	12 Taiwan	13 E-Iran	14 German	15 Russia	16 Czecho	17 N-N	18 C-N	19 S-Sotho	20 S-T
1	—																			
2	0.3296	—																		
3	0.3476	0.2933	—																	
4	0.8526	0.7934	0.5820	—																
5	1.2264	1.0417	1.1660	1.2176	—															
6	1.2030	1.4251	0.9256	0.8801	0.9403	—														
7	1.3680	1.3560	1.4294	1.5473	0.6304	0.8445	—													
8	1.2899	1.3388	1.1798	1.1743	0.9938	0.8239	0.9130	—												
9	1.4857	1.4983	1.7166	1.1164	1.0968	1.3703	0.9309	0.8278	—											
10	1.5469	1.5550	1.6460	0.9591	1.0183	1.1303	1.0487	1.2011	0.3694	—										
11	1.5520	1.4850	1.6934	1.1177	1.0210	1.1977	0.8523	0.8339	0.2387	0.2966	—									
12	1.5614	1.7923	1.7618	1.2854	0.9639	0.8818	0.6678	0.8624	0.4736	0.4259	0.3584	—								
13	1.2376	1.1462	1.1930	1.1396	1.4214	1.1400	0.9512	1.6806	1.1486	0.9460	1.1873	1.1549	—							
14	1.3076	1.2290	1.3744	1.4824	1.2114	1.3054	1.3402	1.1482	1.0987	0.9388	0.9433	0.9413	1.1895	—						
15	1.4709	1.3168	1.5176	1.6691	1.0742	1.3236	0.9774	0.8087	0.8501	0.9660	0.8193	1.0429	0.9489	0.5380	—					
16	1.4711	1.3776	1.5606	1.6460	0.8928	1.1838	0.9811	0.6375	0.9329	1.0648	0.8051	0.9200	1.3762	0.4050	0.2696	—				
17	0.7808	0.8413	0.8622	1.1509	1.3160	1.3117	1.2204	1.5458	1.4566	1.5265	1.7192	1.5406	0.7003	1.1909	1.4065	1.4490	—			
18	0.7051	0.8438	0.6342	0.8631	1.4654	1.0816	1.4122	1.2936	1.6060	1.6879	1.8221	1.5552	0.8517	1.2834	1.5135	1.5178	0.2394	—		
19	0.6803	0.7371	0.6559	0.9088	1.3917	1.2575	1.4154	1.5950	1.6200	1.5879	1.8264	1.5809	0.7448	1.1159	1.5018	1.5178	0.1842	0.1583	—	
20	0.6899	0.9124	0.7246	0.9254	1.4161	1.1042	1.3060	1.3744	1.5100	1.5528	1.7959	1.5284	0.7544	1.4043	1.5041	1.5817	0.1860	0.1432	0.2098	—

TABLE 6. Contribution rate and co-ordinate score of multidimensional scaling

	Dimension			
	1	2	3	4
Eigenvalue	7.614	2.254	2.111	1.529
Contribution rate	57.123	16.909	15.839	10.128
Cumulative contrib.	57.123	74.033	89.872	100.000
Scores for each sample				
New South Wales	0.6526	−0.1850	0.1975	−0.1915
South Australia	0.6166	−0.0662	0.3569	−0.4411
Roonka	0.7854	−0.3623	0.2799	−0.0609
Papua New Guinea	0.3644	−0.6402	−0.4230	−0.4021
Malay-Indonesian	−0.2870	−0.3009	0.2970	0.1400
Bornean	−0.0359	−0.4637	−0.0803	0.5227
Early Thai	−0.4037	−0.0136	−0.0190	0.5721
Jomonese	−0.4348	−0.4393	0.4818	0.1518
Japanese	−0.7029	−0.0099	−0.2792	−0.2442
Chinese	−0.6821	−0.0408	−0.4923	−0.2771
Korean	−0.9033	−0.1784	−0.1384	−0.3040
Taiwanese	−0.7746	−0.0548	−0.3463	0.2648
Early Iranian	0.1896	0.5121	−0.5865	0.0524
German	−0.2982	0.5210	0.2806	−0.2843
Russian	−0.5636	0.5018	0.3504	−0.0662
Czechoslovakia	−0.6236	0.2969	0.5443	0.0363
Natal Nguni	0.6882	0.3976	−0.1086	0.1205
Cape Nguni	0.8152	0.0995	−0.0230	0.1870
Southern Sotho	0.8275	0.2935	−0.0996	−0.0029
Shangana Tonga	0.7702	0.1053	−0.1922	0.2268

RESULTS

Cluster analysis and multidimensional scaling

First, average linkage clustering technique was applied to the Q-mode correlation matrix between pairs of samples (Fig. 1). The correlation matrix is not shown because of its unwieldy size. In the first main cluster, three groups are discernible; the African-Australian samples, the Melanesian samples, and the West Asian early Iranian sample. The second main cluster consists of the European samples, the East Asian samples, the Polynesian-Micronesian samples, and the Southeast Asian samples, including the Jomonese sample. Within this cluster, the Southeast Asian cluster is separated from other regional groups. The European samples cluster with the East Asian-Pacific groups.

Next, multidimensional scaling was applied to the same distance matrix. Table 3 shows the information obtained from this dimension-reduced procedure. Figure 2 is a plot of the samples on the 1st and 2nd axes, which express 74.9% of the total variance. With the possible exception of the Micronesian-Polynesian samples, the separation of the geographical groups in the scattergram provides a relatively accurate interpretation of intergroup relationships. In the western part of the Old World, a rough morphological cline is recognized from Africa to Europe through West Asia. In the same manner, the clinal variation of the craniofacial features from Australomelanesian to Southeast Asian, and then to East Asian groups, are indicated in the eastern part of Eurasia and the western Pacific region.

Within the Polynesian-Micronesian groups, the Oahu and Hawaiian samples occupy a peripheral corner of the diagram. These two samples are inferred to be pre-contact, although a recent re-study (Collins and Armstrong, 1994) indicates some of the specimens are from the post-1778 period. The several Melanesian samples show close affinities with each other, and form a single cluster.

The spread of human groups into remote Oceania, including island Melanesia, did not begin until well after the Pleistocene (Bellwood, 1989). Taking this fact into account, the Polynesian-Micronesian samples and the island Melanesian samples are excluded in the following analyses, so that craniofacial variation in the more anciently populated parts of the Old World can be elucidated more clearly.

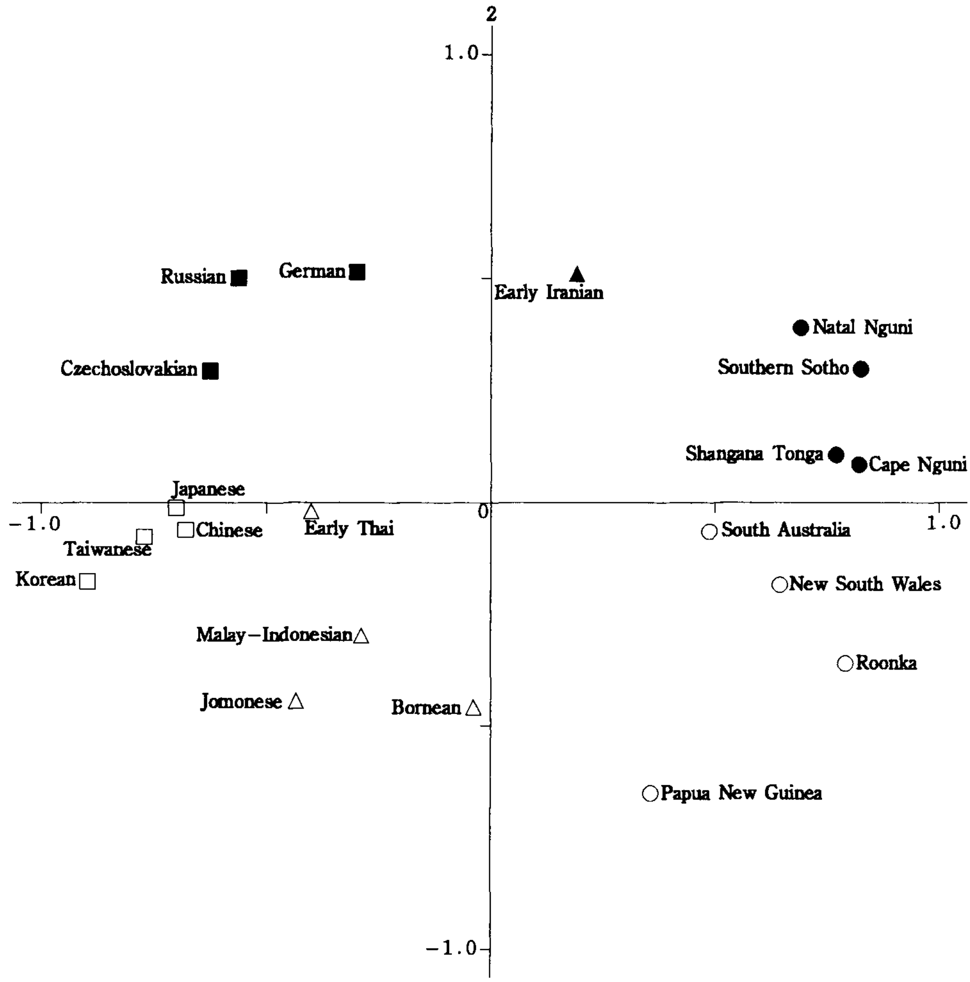

Fig. 4. Two-dimensional plot by multidimensional scaling applied to the distance matrix based on Q-mode correlation coefficients. In this graph, 74.0% of the total variance is accounted for. For description of symbols, see Fig. 2.

Figure 3 shows the results of average-linkage clustering technique based on the Q-mode correlation coefficients given in Table 4. Table 5 gives the absolute distance matrix calculated from multidimensional scaling based on the Q-mode correlation coefficients between pairs of samples. Table 6 shows the final results of multidimensional scaling. The scattering pattern shown in Figure 4 summarizes the inter-population relationships obtained from the first two dimensions. In this Figure, 74.0% of the total variance is accounted for. Two relatively distinct clusters are visible in both Figures 3 and 4. The first constellation includes the African and early Iranian as well as Australian and Papuan samples. The second consists of the European and East/Southeast Asian samples. The early Iranian sample is plotted at an intermediate position between the African and European samples in Figure 4. The second axis divides the samples into two geographical groups: a western region, represented by Afro-European, including West Asia, and an eastern group, representing Australasia and East Asia. As was indicated in Figure 2, the African and Australian samples show closer affinities with each other

TABLE 7. Result of Q-mode factor analysis

Population name	Factor loadings					
	FC-1	FC-2	FC-3	FC-4	FC-5	FC-6
Eigenvalues	7.6044	2.6853	2.5907	1.9756	1.4510	1.1150
Proportions	0.3801	0.1342	0.1295	0.0987	0.0725	0.0557
Cumulative proportions	0.3801	0.5143	0.6438	0.7425	0.8150	0.8707
New South Wales	0.6631	−0.2774	−0.2801	−0.2459	0.1633	−0.1712
South Australia	0.6113	−0.2411	−0.4251	−0.4056	0.4147	−0.0619
Roonka	0.7529	−0.4377	−0.3549	−0.1211	0.0161	0.1616
Papua New Guinea	0.3395	−0.6739	0.2481	−0.3362	−0.2734	0.1831
Malay-Indonesia	−0.2687	−0.2794	−0.2884	0.3761	0.5147	−0.0046
Bornean	−0.0394	−0.4107	0.0247	0.6298	−0.3366	0.5055
Early Thai	−0.3777	−0.0262	0.0869	0.6806	0.4992	−0.1308
Jomonese	−0.4108	−0.2395	−0.4407	0.2929	−0.4960	−0.3877
Japanese	−0.6960	−0.0791	0.3861	−0.2991	−0.0173	−0.4427
Chinese	−0.6667	−0.1325	0.5376	−0.3477	0.0471	0.1566
Korean	−0.8515	−0.1802	0.2560	−0.2930	0.0268	−0.1304
Taiwanese	−0.7346	−0.0854	0.4199	0.1762	−0.1193	−0.0687
Early Iranian	0.2011	0.4198	0.5828	0.0047	0.3080	0.3728
German	−0.3042	0.6018	−0.3262	−0.3319	−0.1977	0.2936
Russian	−0.5349	0.5872	−0.3959	−0.1062	0.0427	0.0995
Czechoslovakian	−0.5894	0.4788	−0.5797	0.0262	−0.1466	0.0145
Natal Nguni	0.7570	0.4519	0.2730	0.1290	0.0694	−0.2308
Cape Nguni	0.8621	0.2264	0.1722	0.1661	−0.3044	−0.1547
Southern Sotho	0.8726	0.3361	0.2064	0.0058	−0.0621	−0.0363
Shangana Tonga	0.8283	0.2353	0.3047	0.2056	−0.1670	−0.2077

than either does to any of the other groups. Clinal variations of craniofacial features in the west and east are also visible in this representation.

Factor analysis

Factor analysis was applied to the Q-mode correlation matrix shown in Table 4. Table 7 summarizes eigenvalues greater than 1.0, proportions of factors, and factor loadings for each sample. Using the first six factors, 87.07% of the total information found in the correlation matrix in Table 4 can be represented. The information summarized in Table 7 is displayed in Figures 5–9.

The relationships between the samples in Figure 5 are quite similar to those shown in Figure 4. In Figure 6, the differences between the Australian and East Asian samples on the one hand, and between the African and European samples on the other, are demonstrated. Figures 7, 8, and 9 display the craniofacial similarities between the European and East Asian samples shown in the previous cluster analyses.

Examination of Figures 5–9 reveals three facts: 1) Euro-African groups including early Iranians and Australian-East Asian groups are clearly separated, suggesting morphologically clinal variation from Africa to Europe through West Asia on the one hand, and from Australasia to East Asian region on the other hand; 2) the East Asian and European samples share similar craniofacial features as contrasted with those of the Australian and African samples, although the difference between East Asian and European samples is larger than that between the Australian and African samples; and 3) the Southeast Asian samples show craniofacial features intermediate between those of the Australian and East Asian groups, and to a lesser extent those of the East Asian and European groups.

Finally, it is now widely accepted that the Jomonese, the Neolithic population in Japan ca. 12,000–2,300 years B.P., were distinguished from modern Japanese by many skeletal and dental characters (Turner, 1987, 1989, 1990, 1992a,b). Since the Japanese islands were detached from mainland Asia by the postglacial rise of the sea-level in the early Holocene, these indigenous peoples may have been isolated geographically and more or less free from mainland Asian influence for about 10,000 years. They developed a unique "Jomon" culture, named after their characteristic pottery with *jomon* (cord-marked) ornaments. The Jomon period was

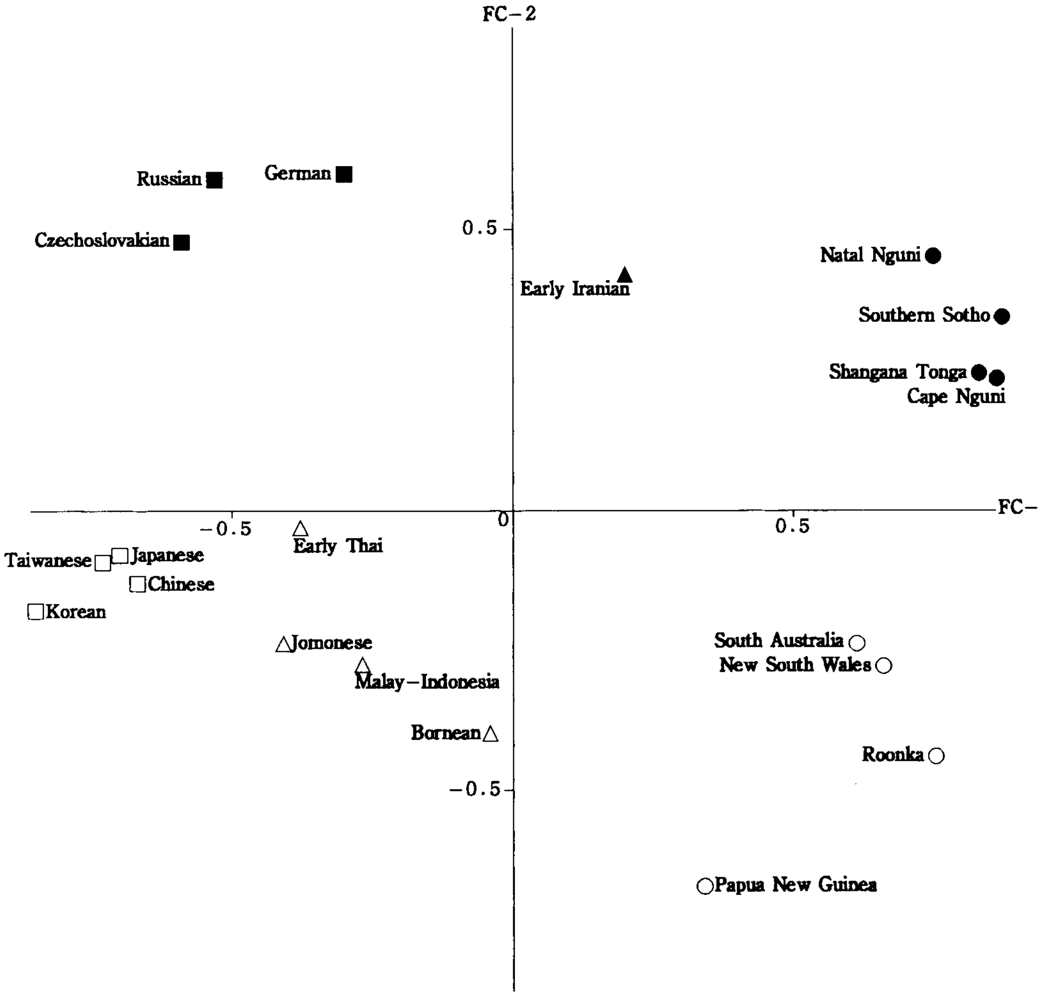

Fig. 5. Scattergram based on the 1st and 2nd factor loadings, expressing 51.4% of the total variance. For description of symbols, see Fig. 2.

succeeded by the Yayoi period. The transition was marked with the introduction of rice farming and metal tools from the continent of East Asia. These changes appear to have been accompanied by a large influx of immigrants from the northeastern part of the Asian continent. The physical characteristics of the latter are more closely related to modern Japanese than they are to the Jomon people.

DISCUSSION

The origins of the multiregional theory can be traced to F. Weidenreich's polycentric views of modern human emergence (Smith et al., 1989). Unlike the classic polycentric models by Weidenreich (1943, 1945, 1951), Coon (1962), and others, however, the present-day regional-continuity model does not claim that local lineages leading to modern humans evolved independently (Smith et al., 1989). Rather, it is asserted that gene flow across population boundaries would have prevented speciation between the regional lineages and thus maintained modern humans as a single species throughout the Pleistocene (Wolpoff, 1985, 1989, 1992). If this is true, regionally close populations would be expected to be more similar to each

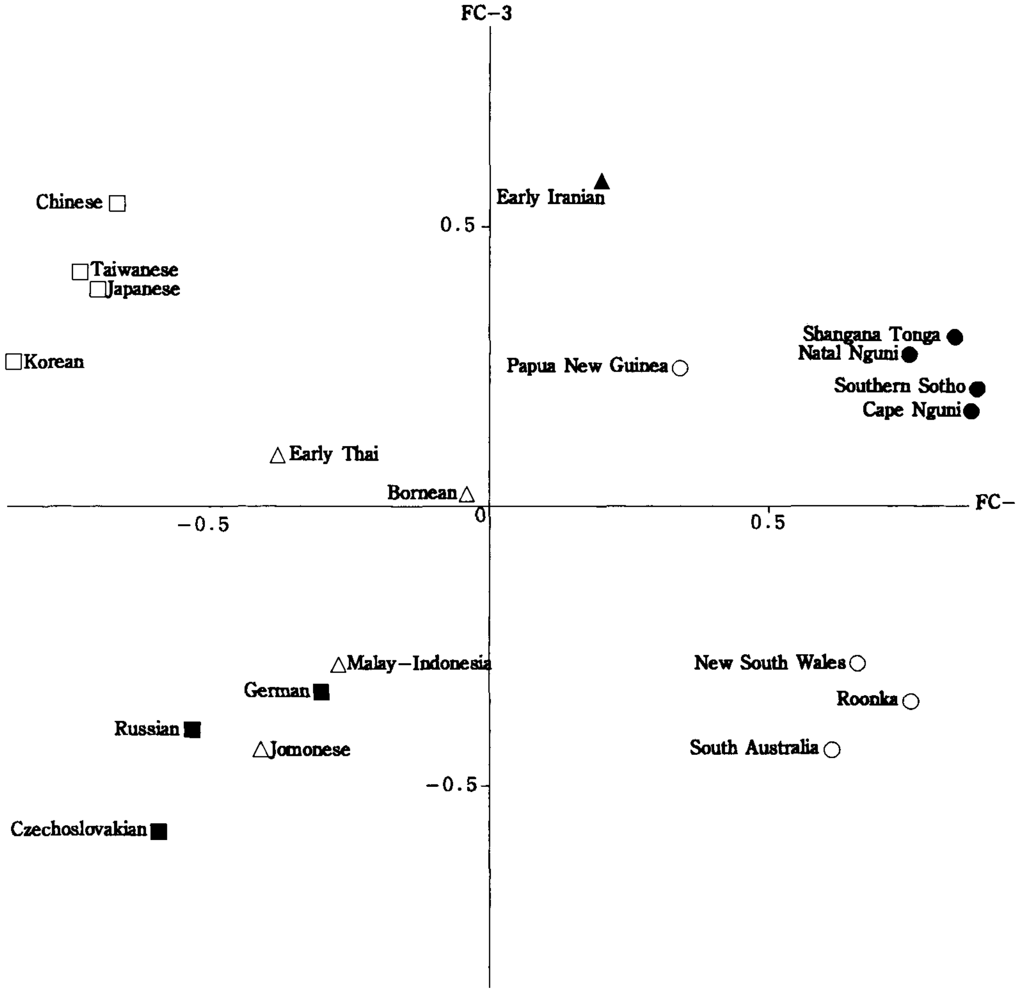

Fig. 6. Scattergram based on the 1st and 3rd factor loadings, expressing 51.0% of the total variance. For description of symbols, see Fig. 2.

other. Howells (1989) pointed out that the multiregional theory predicts that the interpopulation (inter-regional) differences should be high and that these differences should be greatest between peripheral populations. The results obtained in the present study contradict this expectation.

The middle and late Pleistocene fossil records for East Asia and Australasia have played a pivotal role in the modern version of the regional-continuity hypothesis (Thorne and Wolpoff, 1981; Wolpoff, 1985, 1989, 1992; Habgood, 1989, 1992). The thesis proposed by Wolpoff et al. (1984), that archaic *Homo erectus* populations in China and Java gradually diverged to produce modern East Asians and Australasians respectively, suggests that these two regional populations share a community which would not include people of other areas (Howells, 1989). The evidence presented here does not accord at all with this hypothesis.

In the present study, Africans and Australians share similar craniofacial morphological characteristics with each other. A good number of investigators have remarked, moreover, that many of the Australasian features are present in late Pleistocene African

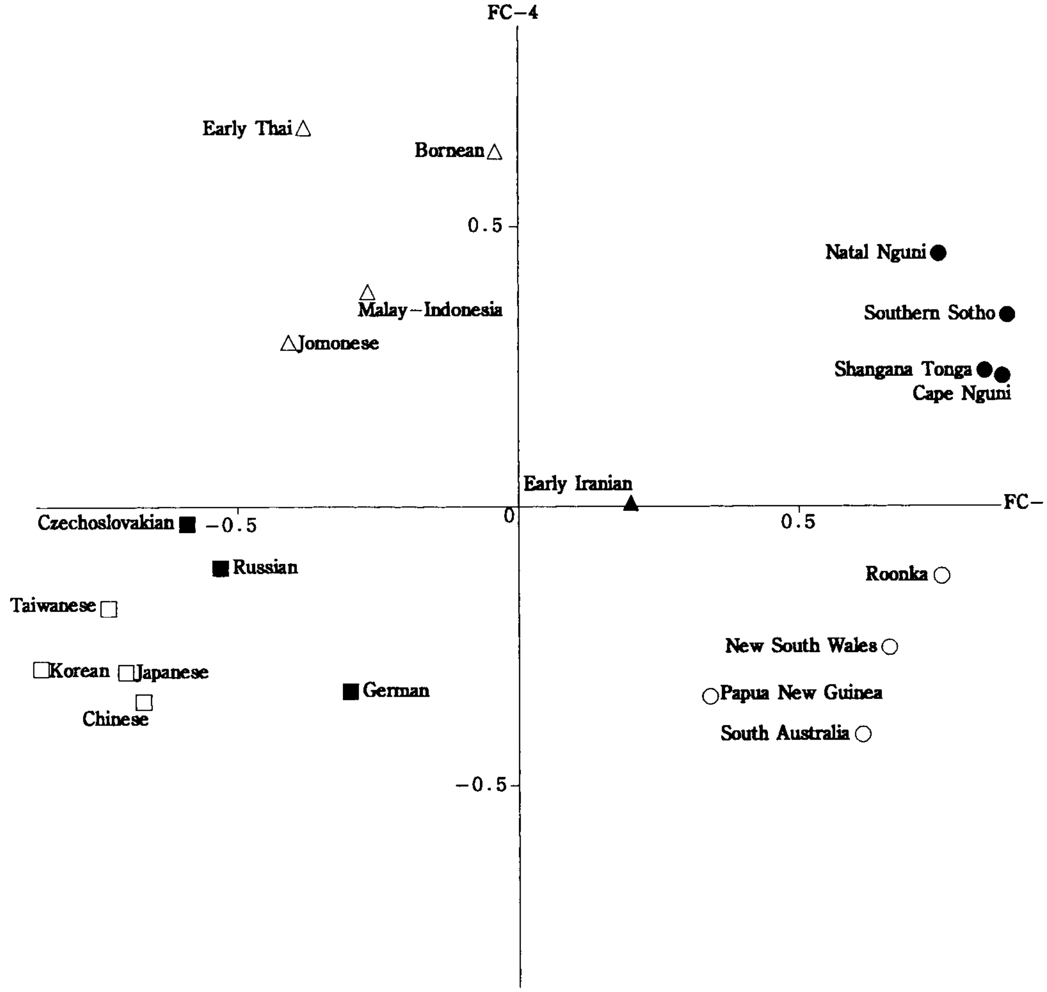

Fig. 7. Scattergram based on the 1st and 4th factor loadings, expressing 47.9% of the total variance. For description of symbols, see Fig. 2.

fossils (Habgood, 1989, 1991; Groves, 1989; Stringer, 1990, 1992; Bräuer, 1992). This may be explained either by the hypothesis of convergent evolution or by the hypothesis that the two populations shared the same ancestral stock at the stage when anatomically modern humans first appeared (Nei and Roychoudhury, 1993). Regarding the problems of the hypothesis of convergent evolution of African traits in the Australian-Papuan stock, Nei and Roychoudhury (1993) emphasized the following two points: 1) the time of divergence between Northeast Asians and Australians-Papuans seems to be too short for the conspicuous difference in phenotypic traits such as pigmentation, hair texture, etc. to evolve; and 2) if there was no migration of African stocks into the Indian subcontinent, then another independent evolution of African-like traits in this area (among Dravidians, Veddas, etc.) must be invoked. Taking this into account in combination with the results presented here, the main pillar of the multiregional evolution concept is considerably weakened.

A number of genetic studies have shown that the first major split of the phylogenetic tree separates Subsaharan Africans from

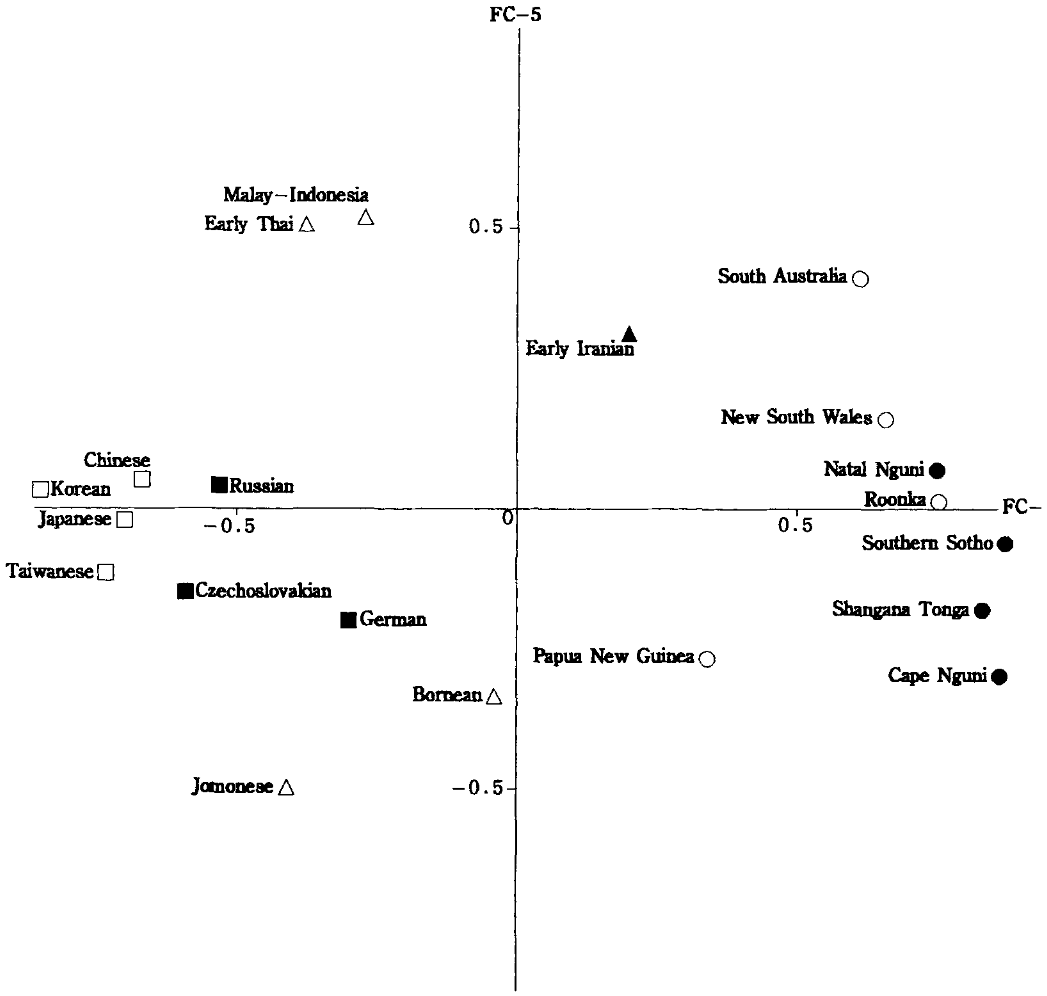

Fig. 8. Scattergram based on the 1st and 5th factor loadings, expressing 45.3% of the total variance. For description of symbols, see Fig. 2.

non-Africans (Horai et al., 1986; Cann et al., 1987; Cavalli-Sforza et al., 1988; Nei and Roychoudhury, 1993; Bowcock et al., 1994). However, morphological traits do not necessarily reflect the genetic background. Morphological differentiation in response to climatic factors is an often-cited explanation for these differences (Beals, 1972; Guglielmino-Matassi et al., 1979; Mizoguchi, 1984; Howells, 1989). Climatically, there are great similarities between Africa and Australia from at least the late Pleistocene to Holocene times (CLIMAP project members, 1976; Kobayashi and Sakaguchi, 1977). The predominant climatic condition found in East Africa to Australia through West Asia and the Indian subcontinent is savannah-like dry heat. In conditions of dry heat, there may be no advantage for the kinds of specialization in craniofacial form observed (Beals, 1972; Bowles, 1977). Most of the Southeast Asian region, on the other hand, has had a wet-heat climate during the Holocene. If anatomically modern humans had spread out of Africa early to India through West Asia and then on to Sundaland and Sahulland, then the migrants to Australia would have evolved under environmental conditions very similar to those of Africa.

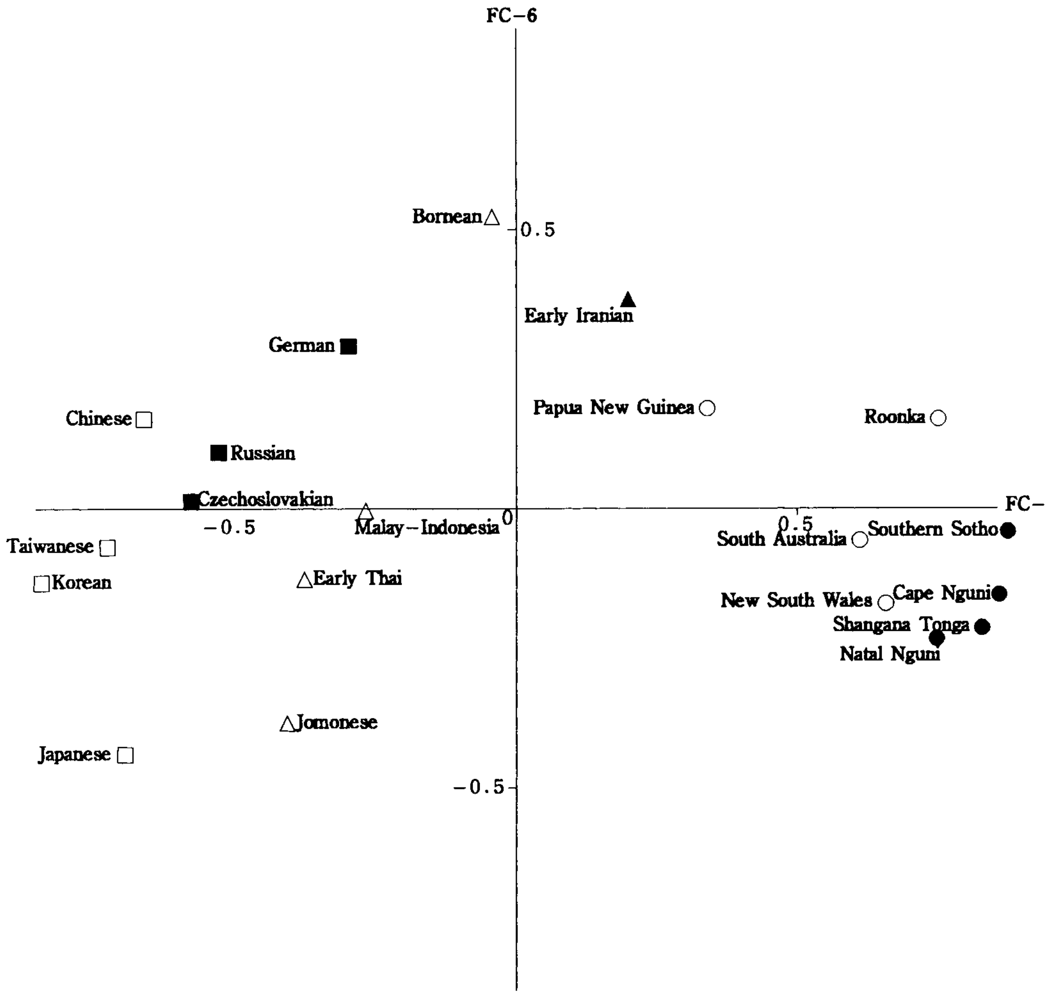

Fig. 9. Scattergram based on the 1st and 6th factor loadings, accounting for 43.6% of the total variance; and 87.1% of the total variance as expressed in Figures 5–9. For description of symbols, see Fig. 2.

The present findings demonstrate evolutionary divergence in craniofacial shape among recent populations of different geographical regions. However, the divergence is limited in the peripheral areas of the Old World, namely Africa and Australia on the one hand and Europe and East/Southeast Asia on the other. If anatomically modern humans evolved simultaneously from *Homo erectus* in at least four geographical areas—Africa, Europe, East Asia, and Australasia—we must hypothesize two opposing trends of evolution while taking into account that gene flow between these four regions has occurred (Nei and Roychoudhury, 1993). There would have had to have been parallel evolution in the direction of identical modern anatomical features in all regions and, secondly, maintenance of regional characters for 500,000 years or more.

In East Asia and Australasia, as well as in the Afro-European region, including West Asia, a morphological cline is evident. A similar pattern of morphological differentiation between Africans and Australians on the one hand and between Europeans and East Asians on the other is evident, although the magnitude of difference in the latter is

greater. This pattern of clinal variation is explicable in terms of the development of phenotypic peculiarities through genetic adaptations of the expanded populations from its center of origin (Coon et al., 1950; Mayr, 1969, 1970; Felsenstein, 1976; Endler, 1977). This may indicate a predominantly single origin for modern human populations.

The results presented in this paper do not support the position that Africa is necessarily the geographical and genetic center from which all anatomically modern humans radiated. At the same time, the model of less extreme replacement with complex hybridization cannot be rejected on the basis of the present evidence. However, the inter-population similarities evident in the craniofacial features presented here are more consistent with the single-origin hypothesis for anatomically modern humans than with the multiregional theory. A predominantly single origin for modern humans is the most parsimonious interpretation of the present evidence.

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